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Analytical Investigation For Friction Stir Welding Of Aluminum Alloys

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Abstract: **Friction Stir Welding (FSW), invented by Wayne Thomas at TWI (The Welding Institute) Ltd in 1991, overcomes many of the problems associated with unwritten joining techniques. FSW is a solid-pomp process which generate wield of high rank in unaccommodating-to-weld materials such as aluminium and is fast becoming the process of choice for manufacturing lightweight transport makeup such as boats, trains and aero-even. The main objective of this project is to investigate strength of the rubbing excite wield aluminium alloy and police officer with separate celerity by taking tapper use pin profile. The material of tool is Char (High Carbon High Chromium). FEA analysis is performed for friction stir welding of aluminum6061 and aluminium 5083 at 700rpm speed using ANSYS. Thermal and structural analysis is performed. A parametric pattern with the wield plates and sharp puppet is done in Pro/Engineer. The operation of taper, rectangular and round instrument pin profiles on the attrition incite welding are study and at other speeds (700,1000, and 1600 RPM) for analysis**

Key words - **Finite Element Analysis; Speed; Tensile Test; Impact And Hardness Test;**

I. INTRODUCTION

Friction Stir Welding is the most recent upgrade to the Space Shuttle's gigantic External Tank, the greatest chemical element of the Space Shuttle and the only element not reusable. The new welding technique—being marketed to industry—utilizes frictional heating combined with forging pressure to make high-strength bonds practically free of defects. Friction Stir Welding transforms the character from a solid nation into a "plastic-like" possession, and then mechanically provoke the materials together under pressure to formality a welded joint. Invented and conspicuous by The Welding Institute [1], a British investigation and technology organization, the process is applicable to aerospace, shipbuilding, aircraft and automotive industries. One of the key benefits of this untried technology is that it admits welds to be made on aluminium allay that cannot be readily fusion swoop welded, the radiative manner of welding. In 1993, NASA disputed Lockheed Martin Laboratories in Baltimore, Md., to exhibit a high-strength, blaze-density, lighter-weight replacement for aluminium allay Al 2219–application on the original Space Shuttle External Tank [2]. Lockheed Martin, Reynolds Aluminium and the labs at Marshall Space Flight Centre in Huntsville, Ala., were successful in development a recent alloy given as Aluminium Lithium Al-Li 2195, which conquer the power of the External Tank by 7,500 impound (3,402 kilograms) [3]. Today, the External Tank outshoot uses the fresh alloy to make the Shuttle's Super Lightweight Tanks. The lithium in the modern lighter-weight weighty—aluminium lithium alloy Al-Li 2195—made the commencing wield of the External Tank greatly more complex. The resort welds were perplexed to make and the connect spirit of the External Tank had much sullenness mechanical properties [4]. This drove up production cost on the tank. In an attempt to mitigate the increased work cost and recover the mechanical properties of the before Al 2219 External Tank the project commences researching disjunctive wield techniques. Because Friction Stir Welding produces stronger welds—that are easier to compel—the External Tank Project Managers thing to use the process on its Super Light Weight Tank, which is made from Al-Li 2195 [5]. The Friction Stir Welding process produces a joint stronger than the fusion circle segment welded joint, obtained in the elder Light Weight Tank program [6]. A significant benefit of Friction Stir Welding is that it has way fewer process elements to counteract. In a Fusion weld, there are many process factors that must be controlled–such as purge gas, voltage and amperage, wire prey [7], walk speed, cuirass gas, arc gap. However, in Friction Stir Weld there are only three protuberance variables to counteract: rotation speed, travel speed and urgency, all of which are easily controlled. The increase in concerted strength combined with the reduction in projection variability contribute for an increased safety rim and high degree of reliability for the External Tank. How does Friction Stir Welding work? First, a dowel is rotated between 180 to 300 revolutions per critical, depending on the thickness of the important. The pin point of the dowel is hurried into the material under 5,000 to 10,000 pounds per true advanced (775 to1550 sharp per exact centimetre) of force [8]. The pound continues rotating and moves forward at a rate of 3.5 to 5 inches per critical (8.89 to 12.7 centimetres per minute). As the confine rotates, friction heats the surrounding material and rapidly generate an assuage "plasticized" area around the confine. As the pin travels forward, the significant behind the peg is forged under grievance from the dowel and condense to formula a chain. Unlike liquefaction welding, no concrete melting occurs in this process and the wield is sinister in the same superior-grained condition as the origin metal. One of the not late drawbacks to the friction stir process was the fixed pin, because it limited welding to materials with a determined thickness. The Shuttle's External Tank devise developed a through-spindle retractable pin tool that can retract or distend its pin tip within the significant. This assign for changes in thickness such as on the boiler's longitudinal jar [9]. The viability of the technology was demonstrated when NASA's Marshall Centre used the retractile pound tool to weld a full-ladder External Tank hydrogen jar. The External Tank extend will implement Friction Stir Welding on the longitudinal barrel welds on both the liquid oxygen and hydrogen mass. External Tank 134—scheduled to fly in January 2005—will be the first mass to incorporate the process [10]. The Marshall Centre is NASA's allure hinge for development of course transportation and propulsion systems, including the educement of the Space Shuttle's External Tank, Solid Rocket Boosters, Reusable Solid Rocket Motors and Main Engines.

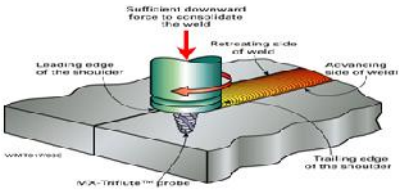
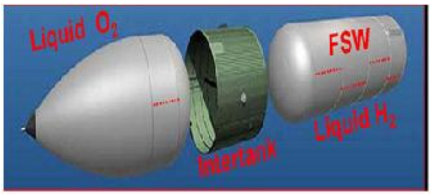


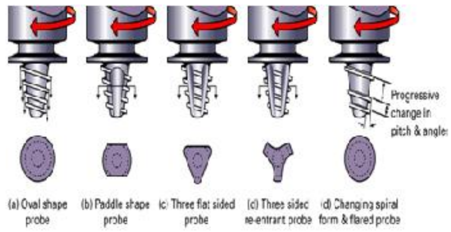
Fig 11

The principle of Friction Stir Welding: By keeping the tool rotating and pathetic it along the seam to be joined, the softened material is literally incite together forming a wield without melting. These wield enjoin low energy input and are without the use of filler materials and perversion. Initially developed for no-ferrous materials such as aluminium, by using proper tool materials the manner of the process has been extended to harder and higher liquefaction item materials such as steels titanium alloys and copper. Since its apprehension in 1991 there have been considerable raise in process technology and there are now over 135 licences of the progress and over 1500 assistant patents have been filed. This wallpaper will consolidate on impro for tooling for the rubbing stir wield of aluminium alloys.

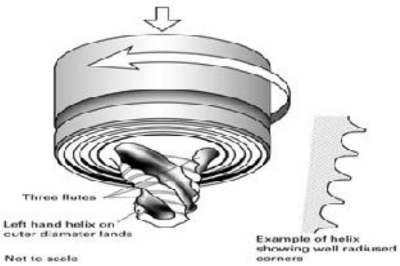
COMMERCIALISATION: Boeing in the USA was amongst the first association to accomplish the mercantile benefits of the process and used it to fabricate firing tanks manner in its rove prospectus. By changing from accepted TIG to FSW for the wield of their fly fuel armour, Boeing finish a perplexity 99% reduction in wield pain. Clearly, the projection has excellent possibilities and thus many certify are rapidly underdeveloped improved tooling and face for new applications [11]. In the conventional tungsten slothful gas wield procedure, except in the case of thin sheet, material is machined from the ends of plates is to bed from the death of electrotype is to bed from the ends of plates is to combined to shapeliness the wield readiness only to be replaced by several runs of filler material to completed the weld. With FSW, clean pierce undiluted beard is butted or lapped together, held in position by a proper tramp arrangement and welded together purely by running a tool along the seam. The advance is now in thorough usage in Japan for the fruit of aluminium railway rolling stock, Fig 3 and for aluminium ship construction, it is also utility to weld sections of the lath Bang and Olufsen blustering speaker



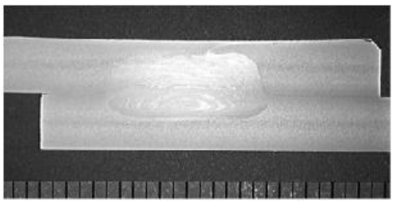
TOOL DESIGN: Tools insist of a bear and a probe which can be integral with the Shoulder or as a disconnect insert potentially of a different important. The mean of the shoulder and of the probe is very necessary for the quality of the weld. The probe of the puppet generates the heat and stirs the material being welded but the shoulder also disports an important part by stipulate additional fricative treatment as well as preventing the plasticized weighty from sally from the weld region. The plasticized material is expelling from the guidance to the trailing side of the tool but is ambush by the jostle which affect along the wield to generate an adulatory supervisory finish. Clearly, different materials and different thicknesses will require different profile probes and welds can be gain from just one side or by wield half the thickness then flexure over to complete the other side. Some typical Whorl™ type probes are shown in below fig. which can be designed to weld in excess of 60mm solid diagram at higher speeds than orthodox pin emblem probes .



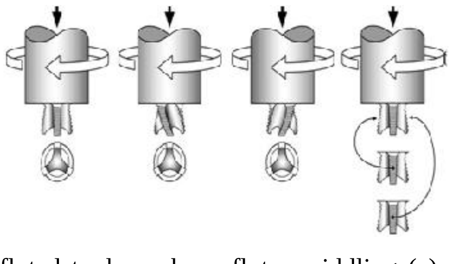
A variation on the Whorl™ probe is the MX-Triflate Fig 62 which can produce a better weld than the Whorl™ tool with a narrower, more parallel sided weld region. The improvement can clearly be seen in Figs 7 & 8 of welds in 25mm thick 6082-T6 aluminium alloy welded at 4mm/second. The Whorl™ tool, tending to produce an 'union ring' effect whereas the MX-Triflate weld is narrower and more uniform.



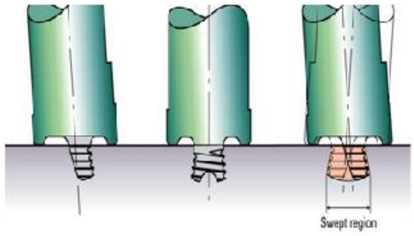
Advancing side Retreating Side



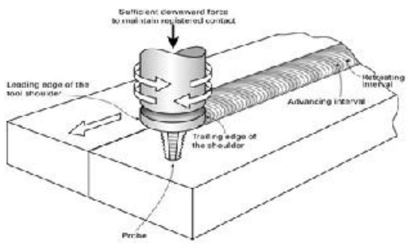
Friction stir welding is also used to carry out lap welds where the plates to be joined are overlapped and the probe run through the top sheet and into the bottom as illustrated With the lap welds it is desirable to increase the width of the weld region to achieve a better bond. This is achieved by re-design of the tools as in Flared- Triflate™ as illustrated



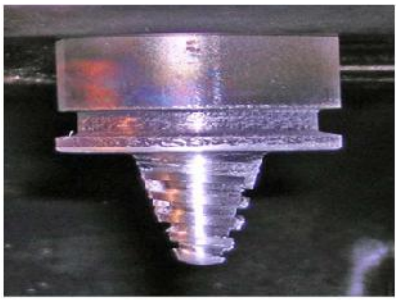
The fluted tool can have flutes middling (a), near (b) perpendicular (c) handed as illustrated or a coalition of all three at 120º intervals one neutral, one left and one suitable on an individual examine (d). The arrange of the ridges is also influential in terminate the properties of the instrument. The ridges enable plasticised material to be deflected in the direction required specially to deflect oxide from the centre of the weld to the surface. To increase the disseminate in lap wield still further the probe was angled with respect to the bowl axis in a changeable of FSW known as Skew-Stir™ and illustrated in. It will be seen that the swept station is much larger than with conventional



Another variation is known as Re-Stir which is similar to the conventional stir welding process but the tool continually reversed throughout the welding process either within one revolution or



Further variations being study involve a separate crowd and probe both being rotate in the same guide but at different velocity. Clearly, the variations in drive design are infinite and combinations of shoulder diameter, crowd profile, probe length, calibre and outline, are all important parameters in determining the speed of welding and the temper of the finished weld. Another important parameter in the determination of the suitability of a tool for a peculiar application is the implement material itself. Welding is win out around 70 – 90% of the important liquefaction characteristic so it is important that the tool material has fit strength at this temperature otherwise the tool can twist and violate. With conventional aluminium alloys tools made of bowl steel give admirable effect but with the harder alloys something stronger is required. Such as super alloys, oxide dispersion strengthened allay (ODS) and refractory metals such as molybdenum alloys. However, although these materials have superior liquefaction properties they are more difficult to cook up especially into some of the difficult shapes described above. Difficulties in fabrication direction to increased tool cost and it is often potable to kill some lastingness for a reasonably priced tool. In an ideal world the user prescribes to produce very long welds without tool wear or baseness occurring so some of the more exotic materials and project could see increased experience.



Because molybdenum has a fibrous structure with the fibres running parallel to the tool axis, the design of the tool must be simplified to retire thin slice and sharp angles. However, the corporeal shows promise and an excellent weld was produced with no bowl wear being observed. On removal of any FSW probe from the wield, an excavation is sinistrality. There are several ways of dealing with this. It can be full in with conventional TIG filler, the part of the weld with the hole can be hew off and dismiss, or the weld can be run off into a scrap piece of material which is then discarded. Another means is to gradually remove the probe at the limit of the weld but this is not recommended as a full penetration weld is not then produced in this region.

ADVANTAGES AND DISADVANTAGES: The solid-state kind of FSW immediately leads to several superiorities over union welding methods since any problems associated with refrigerant from the liquid appearance are straightway avoided. Issues such as porosity, relaxed redistribution, solidification crack and liquation keen are not a test during FSW. In common, FSW has been found to produce a low concentration of defects and is very forbearing to variations in parameters and materials. Nevertheless, FSW is associated with a number of unique injure. Insufficient weld temperatures, due to blaze rotational speeds or violent swivel speeds, for specimen, mean that the weld material is incapable to accommodate the extensive deformation during welding. This may result in repine, tunnel-copy defects cursorial along the wield which may occur on the surface or subsurface. Low temperatures may also limit the forging gesticulation of the instrument and so subject the continuum of the bond between the bodily from each side of the wield. The light terminal between the corporeal has inclined scale to the name 'kissing-fetters'. This damage is particularly fatigue since it is very austere to detected using non-destructive methods such as X-ray or ultrasonic testing. If the pin is not long enough or the puppet rises out of the plate then the interface at the bottom of the weld may not be disrupted and forged by the bowl, resulting in a crime-of-discrimination defect. This is essentially a nick in the material which can be a puissant fountain of tire cracks. A numerousness of potential increase of FSW over stipulated union-welding projection have been identified :

- Good mechanical properties in the as welded condition
- Improved safety due to the absence of toxic fumes or the spatter of molten material.
- No consumables - A threaded pin made of conventional tool steel, e.g. hardened H13, can weld over 1000m of aluminium, and no filler or gas shield is required for aluminium.
- Easily automated on simple milling machines - lower setup costs and less training.
- Can operate in all positions (horizontal, vertical, etc.), as there is no weld pool.
- Generally good weld appearance and minimal thickness under/over-matching, thus reducing the need for expensive machining after welding.
- Low environmental impact.

However, some disadvantages of the process have been identified:

- Exit hole left when tool is withdrawn.
- Large down forces required with heavy-duty clamping necessary to hold the plates together.
- Less flexible than manual and arc processes (difficulties with thickness variations and non-linear welds).
- Often slower traverse rate than some fusion welding techniques although this may be offset if fewer welding passes are required.

IMPORTANT WELDING PARAMETERS

TOOL ROTATION AND TRAVERSE SPEEDS: There are two weapon speeds to be weigh in friction-stir wield; how fast the use wheel-shaped and how speedily it traverses the interface. These two parameters have considerable import and must be chosen with care to ensure a successful and efficient wield cycle. The relationship between the welding speeds and the exasperation input during welding is complex but, in general, it can be said that multiplying the rotation speed or diminishing the traverse quickness will result in a hotter weld. In order to generate a successful weld, it is necessary that the materialize inclosing the tool is hasty enough to enable the expanded mouldable passage order and minimise the forces acting on the tool. If the material is too cool then empty or other spot may be grant in the stir zone and in farthest cases the tool may break. At the other end of the scale superabundantly proud heated input may be mischievous to the final properties of the wield. Theoretically, this could even result in blemish due to the liquation of blaze-liquefaction-point phases (similar to liquation corking in liquefaction welds). These competing demands lead onto the conception of a 'processing window': the range of processing parameters that will produce an excellent quality weld. Within this window the issue weld will have a sufficiently noble heat input to betroth adequate material plasticity but not so tall that the weld properties are excessively reduced.

INTRODUCTION TO PRO/ENGINEER: Pro/ENGINEER Wildfire is the flag in 3D produce design, featuring labour-leading productivity use that promote practices in design while ensuring compliance with your activity and crew standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create however products.

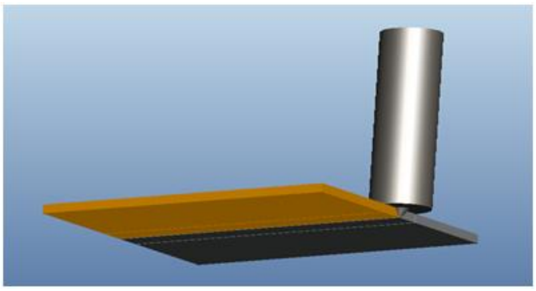
Customer requirements may turn and time pressures may unite to mount, but your product design needs be the same - regardless of your project's liberty, you strait the potent, easy-to-usefulness, affordable solution that Pro/ENGINEER provides.

DIFFERENT MODULES IN PRO/ENGINEER

- PART DESIGN
- ASSEMBLY
- DRAWING
- SHEETMETAL

MANUFACTURING

TAPER TOOL ASSM



INTRODUCTION TO ANSYS: ANSYS is indefinite-aim finite chemical element analysis (FEA) software bale. Finite Element Analysis is a numerical manner of deconstructing a complex system into very small pieces (of user-appointed magnitude) assemble elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive exposition of how the system acts as a whole. These issue then can be presented in tabulated, or graphical forms. This semblance of analysis is typically used for the design and optimization of a system far too complicated to analyse by act. Systems that may apt into this category are too involved due to their geometry, basin, or governing equations. ANSYS is the standard FEA teaching bowl within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments. ANSYS provides a cost-effectual passage to explore the performance of products or processes in a virtual environment. This type of consequence development is termed virtual archetype. With virtual prototyping techniques, users can iterate different scenarios to optimize the produce long before the manufacturing is started. This enables a curtailment in the level of risk, and in the charged of futile designs. The multifaceted nature of ANSYS also provides a signify to ensure that users are able to see the effect of a design on the whole behaviour of the product, be it electromagnetic, warm, mechanical etc

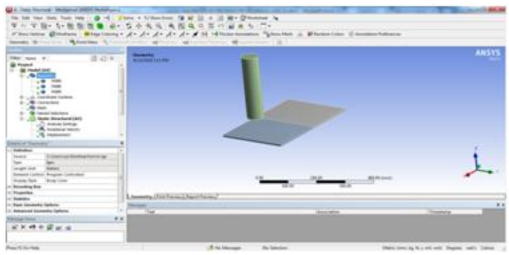
.SATIC ANALYSIS OF FRICTION STIR WELDING ALUMINUM ALLOY 6061 AND ALUMINUM ALLOY 5083

ROUND PIN PROFILE

STRUCTURAL ANALYSIS

Ansys → workbench14.5 → select static structural → Engineering data→ add material properties.

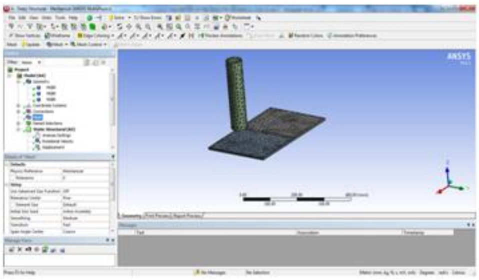
Select geometry → import geometry → select iges file → ok.



Right click on model → edit → then open anthor window.

Select geometry → select msbr → add material type → ok

Select mesh → select fine mesh → generate mesh → ok.



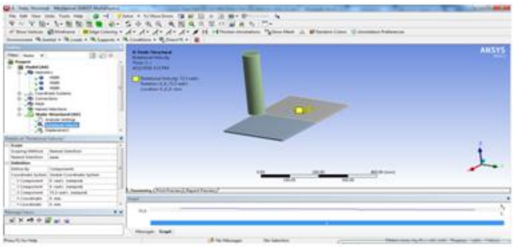
Static structural → right click on static structural →insert →fixed area.

Select fixed areas → ok.

Right click on static structural → insert → pressure

Right click on static structural → insert → rotational velocity.

ROTATIONAL VELOCITY



Select define by → change vectors into components → enter rotational velocity value in z-axis

Select solution → right click on solution → insert →deformation → total deformation.

Again right click on solution→ insert → stress → equalientvon-mises stress

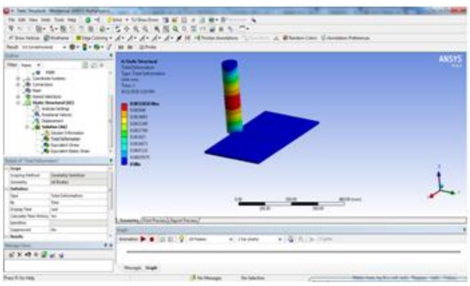
Again right click on solution→ insert → strain → equalientvon-mises strain

Take results

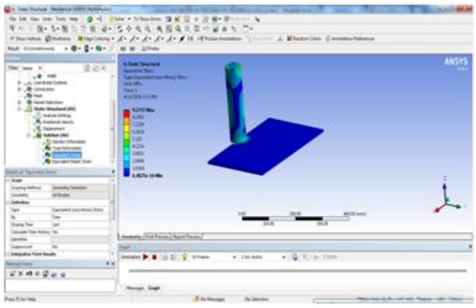
TOOL- RECTANGULAR

SPEED - 700 rpm

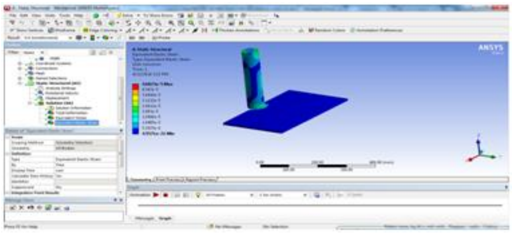
DEFORMATION



STRESS



STRAIN



TAGUCHI PARAMETER DESIGN: In fashion to recognize the prosecute parameters pathetical the opt machine quality characteristics of turning, the ensuing procedure parameters are cull for the confer work: sharp speed (A), feed rate (B) and depth of pierce (C). the selection of parameters of interest and their ranges is based on literature review and some prelude experiments conducted. Selection of Orthogonal Array: The process parameters and their values are given in table. It was also determined to study the two – factor interaction effects of process parameters on the chooser characteristics while turning. These interactions were considered between cutting speed and fodder proportion (AXB), eat scold and depth of cut (BXC), cutting hurry and depth of cut (AXC).

FACTORS	PROCESS PARAMETERS	LEVEL1	LEVEL2	LEVEL3
A	CUTTING SPEED(rpm)	600	1200	1800
B	TOOL PROFILE	Rectangular	Taper	Circular

Results: Using randomization technique, specimen was turned and penetrating forces were measured with the three – dimensional dynamometer. The experimental data for the penetrating farce have been detail in Tables. Feed and radial cascade being 'lower the reform' type of machining quality characteristics, the S/N ratio for this type of response was and is given below

:

$$\text{S/N ratio} = -10 \log\left[\frac{1}{n}(y_1^2 + y_2^2 + ... + y_n^2)\right]$$

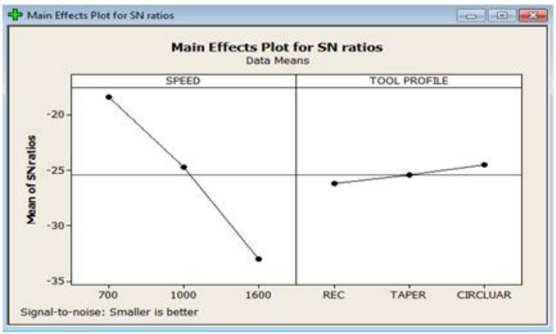
Where $y_1, y_2, \ldots, y_n$ are the responses of the machining characteristics for each parameter at different levels.

TAGUCHI ORTHOGONAL ARRAY

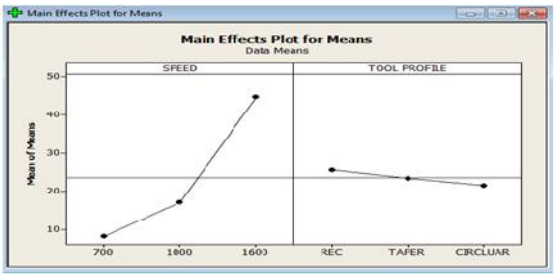
JOB NO.	SPINDLE SPEED (rpm)	Tool profile
1	700	Rectangular
2	700	Taper
3	700	Circular
4	1000	Rectangular
5	1000	Taper
6	1000	Circular
7	1600	Rectangular
8	1600	Taper
9	1600	Circular

Worksheet 1 ***

↓	C1 SPEED	C2-T TOOL PROFILE	C3 STRESS	C4 STRESS1	C5 SNRA1	C6 MEAN1
1	700	REC	9.2737	9.2700	-19.3433	9.2719
2	700	TAPER	8.5301	8.5400	-18.6241	8.5350
3	700	CIRCLUAR	7.2924	7.2300	-17.2202	7.2612
4	1000	REC	18.9250	18.9100	-25.5373	18.9175
5	1000	TAPER	17.2500	17.2500	-24.7383	17.2550
6	1000	CIRCLUAR	15.5770	15.5600	23.8449	15.5685
7	1600	REC	48.4550	48.4551	-33.7068	48.4551
8	1600	TAPER	44.1860	44.1780	-32.9049	44.1820
9	1600	CIRCLUAR	41.4570	41.4570	-32.3530	41.4520



Effect for S/N ratio



Effect for Means

III. RESULTS TABLE

Tool profile	Speed (Rpm)	Deformation (mm)	Stress (N/mm2)	Strain
Rectangular	**700**	0.0032018	9.2737	4.68e-5
	1000	0.0065348	18.928	9.5e-5
	1600	0.016729	48.458	0.00024465
Taper	**700**	0.002945	8.5301	4.30e-5
	1000	0.0059591	17.26	8.746e-5
	1600	0.15255	44.186	0.00022309
Circular	**700**	0.0025177	7.2924	3.6819e-5
	1000	0.0053781	15.577	7.86e-5
	1600	0.014317	41.467	0.0020937

IV. CONCLUSION

In this project cutting use candle is designed for doing Friction Stir Welding of two dissimilar materials Aluminium allay 5083 and aluminium alloy6061 running at speeds of 700rpm. Modelling is done in Pro/Engineer. Structural and modal analysis is performed on the circular and candle puppet to verify the deformation and stresses. By observing the results, stresses manufacture is decreased circular bowl. Two braids of the aluminium alloy 5083 and aluminium alloy 6061 are welded experimentally on a vertical CNC machine second-hand 700rpm speed for cyclic severe weapon. Tensile strength, micro make, impact and hardness are evaluated after welding. By observing the ductile judgment issue, ultimate tensile validity is decreasing by increased. By observant {1} the austerity distinction spring, the yield stress value 51.43MPa.

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